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by Boyd M. Witherow

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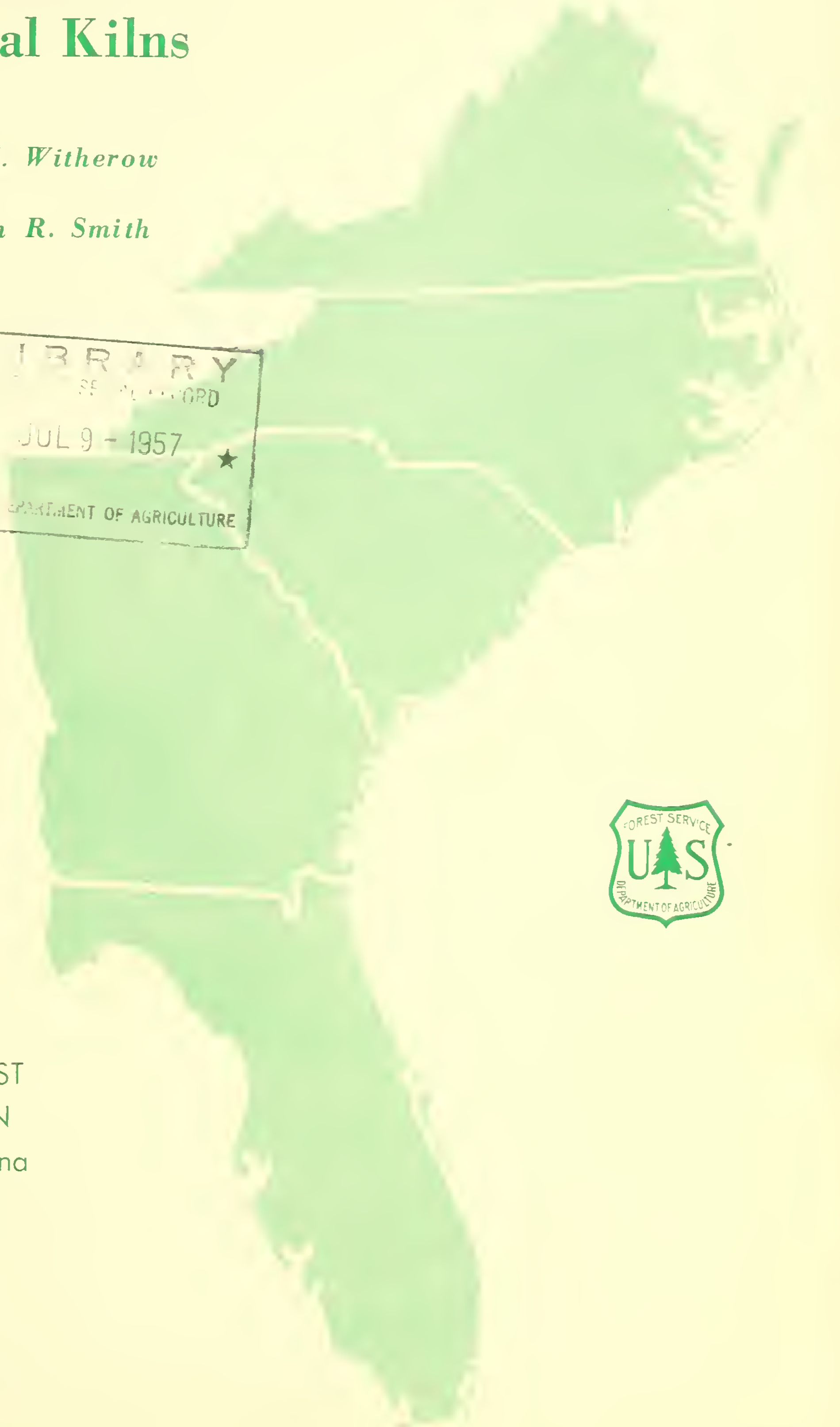

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ACKNOWLEDGEMENT

This study was made possible by the cooperative efforts of the N. C. Forest Service, N. C. Department of Conservation and Development; the Division of Forest Utilization Research and the Athens-Macon Research Center of the Southeastern Forest Experiment Station; the Forest Products Laboratory, Madison, Wisconsin; and the Western Carolina Charcoal and Chemical Company, Asheville, N. C. Special recognition is due Mr. Graham Chamblee, Forest Supervisor, Bladen Lakes State Forest, who constructed and operated the kilns used in the study and gave invaluable assistance.

COST OF OPERATION FOR THREE TYPES OF CHARCOAL KILNS

by

Boyd M. Witherow and Walton R. Smith
Division of Forest Utilization Research

INTRODUCTION AND SUMMARY

The current upswing in use of charcoal for backyard cooking, picnics, and barbecuing creates a large domestic market, especially during the warm-weather months. This increased demand is not being met by present producers, and so there is widespread interest in "getting into the charcoal business."

A considerable volume of charcoal is produced in rather inexpensive kilns of sheet metal or masonry block. Because of the increasing demand for information about the relative merits of such kilns, their operating procedures, charcoal yields, and operating costs, the U. S. Forest Service, in cooperation with the North Carolina Department of Conservation and Development, North Carolina Forest Service, conducted a charcoal-kiln study at the Bladen Lakes State Forest near Elizabethtown, North Carolina. Four kilns were used in the study. Two were $\frac{1}{2}$-cord sheet metal units (fig. 1), one was a $1\frac{1}{2}$-cord sheet metal unit (fig. 2), and the fourth a double-wall masonry block structure of 2-cord capacity (fig. 3).

Of the three types studied, the 2-cord cinder block kiln produced the highest yields and had the lowest depreciation cost. It was, for these reasons, the most profitable to operate, though labor cost during burning and cooling periods was higher. On a basis of present-day prices for wholesale charcoal, none of the kilns studied showed a safe margin of profit. Opportunities to increase the profit margin lie in mechanizing the handling of wood and charcoal, operating batteries instead of single kilns, obtaining cheaper wood, and using larger kilns.

METAL KILNS

Two of the metal kilns were standard $\frac{1}{2}$-cord units purchased by the North Carolina Forest Service from a commercial fabricator in Georgia. These kilns are readily portable, having two circular sections and a separate, coned lid. The bottom section is 14-gage sheet metal and the upper section and lid are 16-gage metal. The two sections and the lid give the kiln a total height of 5 feet 6 inches. The diameter of the base is 7 feet, while the top section and lid diameter is 4 feet 6 inches, which gives the assembled kiln its truncated cone shape. All sections are flanged to stiffen the shell. These

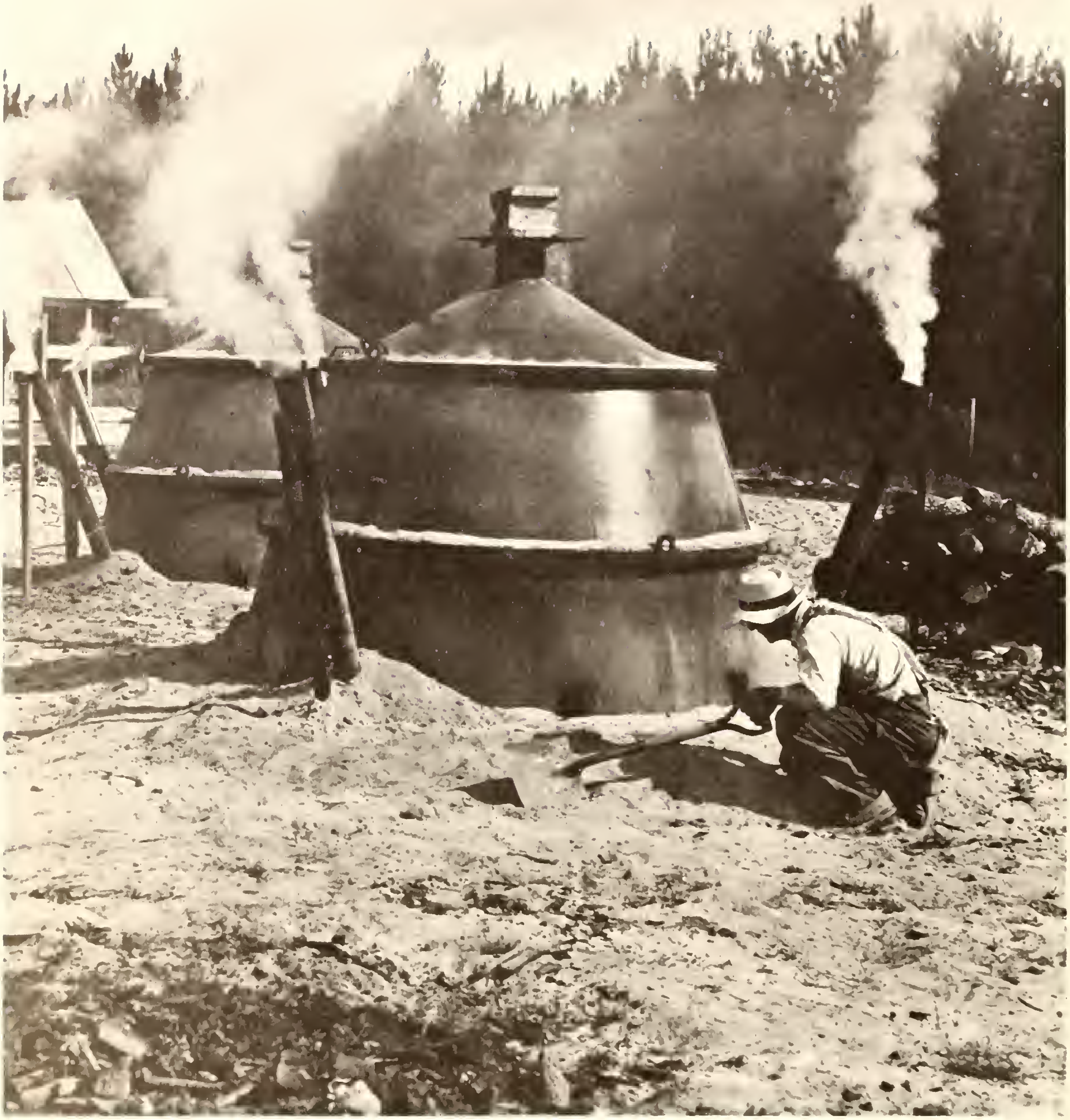

Figure 1.--One-half-cord sheet metal kiln, fully assembled and in the coaling phase.
Photo by N. C. Dept. of Conservation & Development

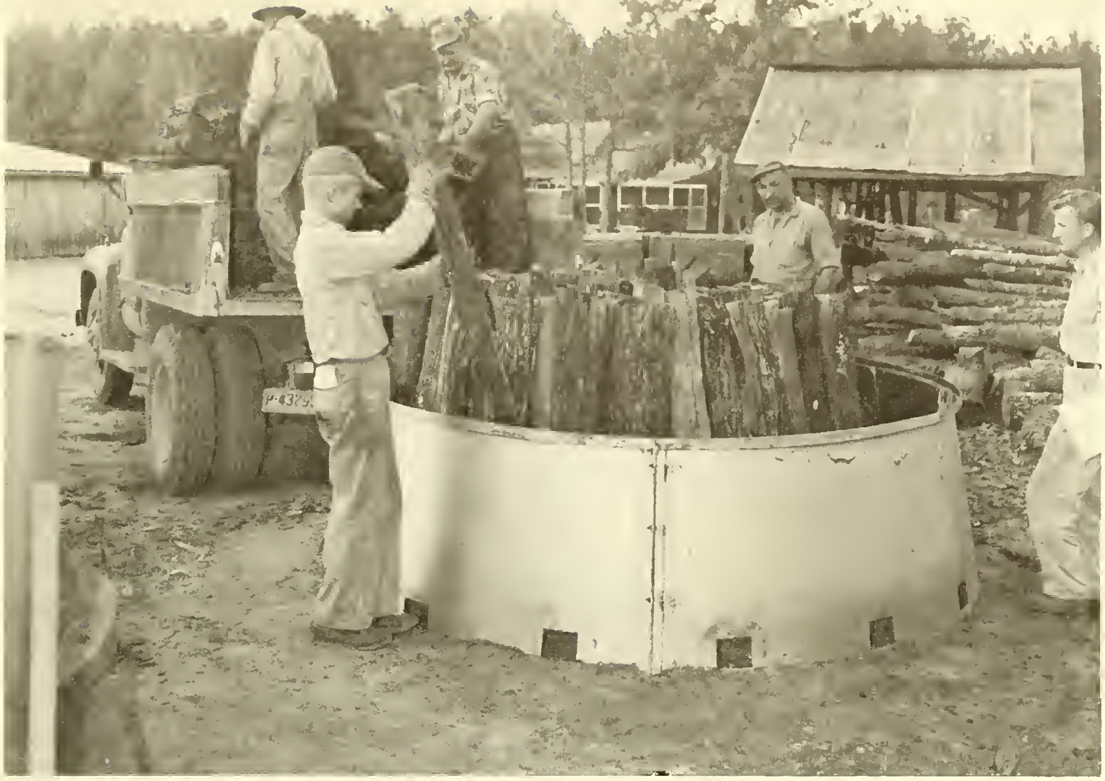

Figure 2.--Bottom section of $1\frac{1}{2}$-cord metal kiln being charged with wood. Note joint where sections are bolted to form the complete bottom ring.

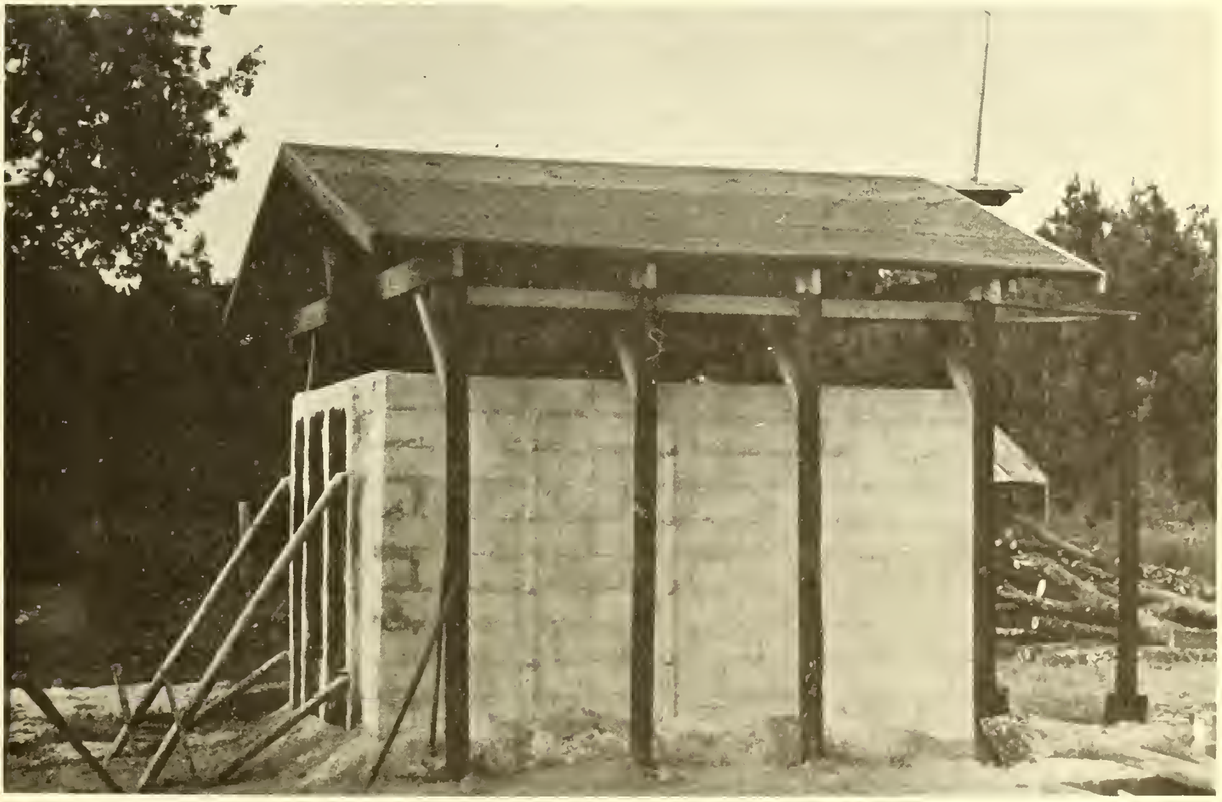

Figure 3.--Two-cord double-wall masonry block kiln. Note propped metal door and independently supported roof.

flanges fit snugly into gutters welded to the upper side of the section beneath (fig. 4). The lid has a short smoke pipe in the center. There are nine 4-inch holes evenly spaced around the base of the bottom section, serving alternately as air inlets and as hot gas outlets. Five-foot cast iron pipes inserted in three of these holes serve as chimneys.

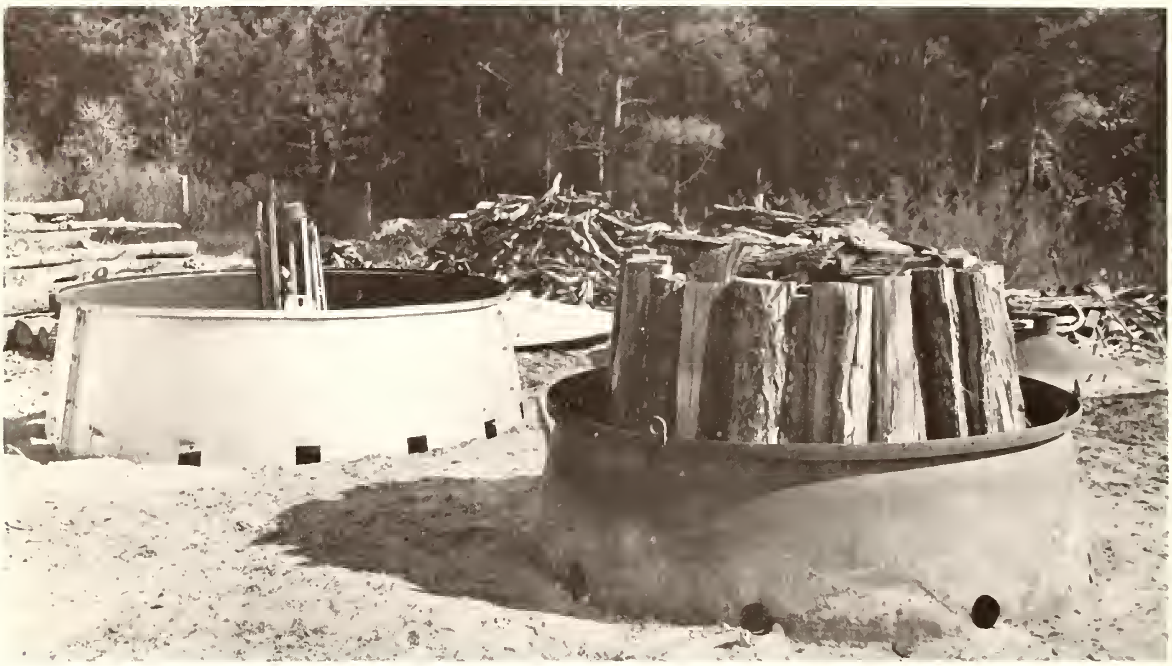

Figure 4.--Bottom half of $\frac{1}{2}$-cord kiln ready for top section. Note gutter for snug fit of top section. In left background, $1\frac{1}{2}$-cord kiln with kindling in place.

The similarly constructed $1\frac{1}{2}$-cord kiln [1] is made entirely of 16-gage steel. It has a base diameter of 10 feet, a top section and lid diameter of 8 feet, and a total height of 7 feet. Due to its increased size and weight, the two kiln sections are each made up of three smaller sections bolted together to form the complete circle (fig. 2). When completely disassembled, the kiln can easily be transported. The lid has a short 6-inch smoke pipe at its center. The bottom section contains fifteen 4-inch by 4-inch holes which serve as air inlets and hot gas outlets. Eight 10-foot smoke pipes are used with this kiln.

MASONRY BLOCK KILN

The masonry block kiln was an experimental unit designed by the Forest Products Laboratory, but built and operated by the North Carolina Forest Service. It is a double-wall structure employing a propped metal door and an externally supported metal ceiling covered with 3 inches of sand.

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[1] Supplied on loan by the Western Carolina Charcoal and Chemical Company, Asheville, N. C.

The entire unit is protected by a wood roof on independent supports. Standard masonry blocks were used throughout, with an 8-inch sand fill between the two walls. Two 8-inch by 8-inch vent ports are located in the ceiling 10 inches behind the door. An 8-inch diameter metal chimney extends from its base at the bottom center of the rear wall to a point 36 inches above the ridge of the roof. The chimney base also contains an 8-inch port where a fire may be built to induce draft in the chimney. The sheet metal door is fitted with angle-iron lugs that serve as stops for the supports used in holding it against the kiln during operation. A coaling chamber 10 feet long, 5 feet 4 inches wide, and 6 feet 8 inches high gives capacity for 2 cords of wood.

WOOD USED

Hardwoods were used exclusively in this study. The bulk came from the red oak group, primarily water (Quercus nigra), southern red (Quercus falcata), and blackjack (Quercus marilandica). The wood, air seasoned approximately 4 months, had reached an average moisture content of 45 percent. Decay was found in the sapwood of much of this material. All wood used was in 4-foot lenghts, both with and without bark (fig. 5).

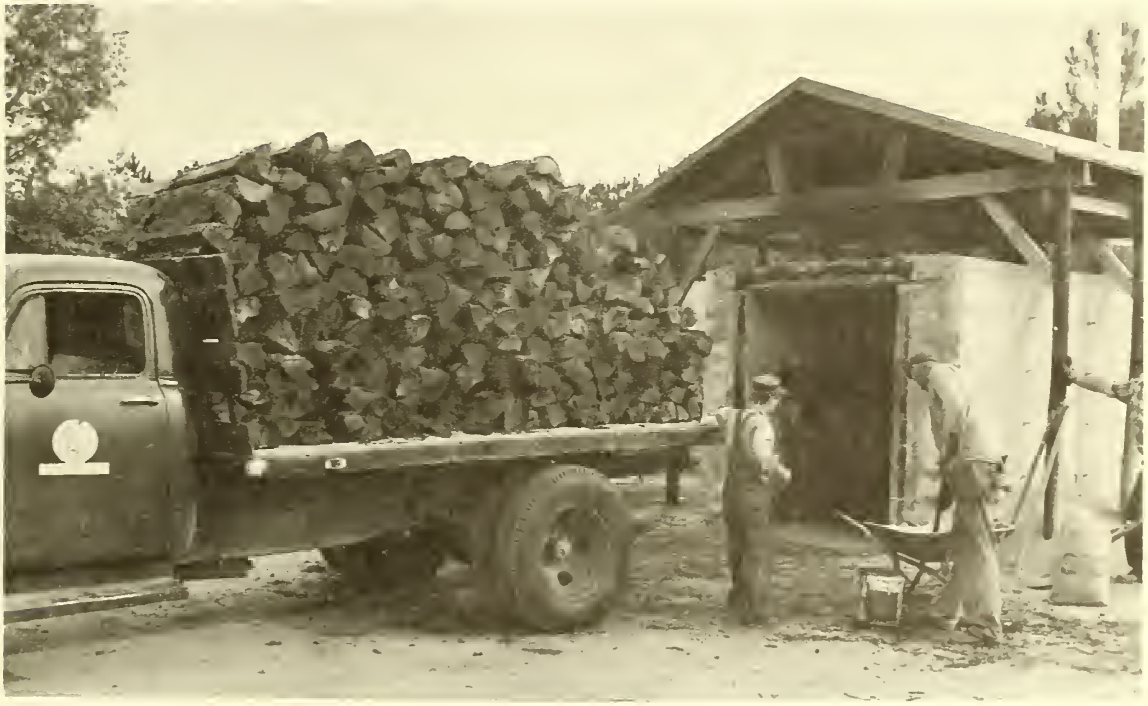

Figure 5.--Type of·wood used as raw material in this study.

The average moisture content was obtained by use of a moisture meter and the ovendry method. Sample sticks were selected at random as the charge was being loaded into the kiln. These sticks were cut in half and a 1-inch moisture content section was sawn from one of the inner faces. A moisture meter reading was then taken on the stick adjacent to the point where the section was removed.

The moisture meter readings averaged within plus or minus 2 percent of the ovendry sample determinations, so the average of all measurements was determined at 45 percent and was used in all the later calculations.

KILN TEMPERATURE DATA

All of the kilns, except one of the $\frac{1}{2}$-cord kilns, were wired with thermocouples to obtain the necessary temperature data (figures 6 through 14). The masonry block kiln was operated to hold the maximum temperature to about 950° F., but the metal kilns were permitted to burn at any temperature reached, as is common in commercial practice. A potentiometer and a microameter [2] calibrated to degrees Fahrenheit for direct reading were used to indicate the temperatures. Time-temperature graphs were made from the recorded data for all but the two runs conducted in the unwired kiln (figures 8 through 14).

THERMOCOUPLE LOCATION

Three thermocouples were placed along the center line of the masonry block kiln at various heights above the floor. No. 1, located at the front, was at midheight; No. 2, in the center, was 18 inches from the ceiling; No. 3, at the back, was 18 inches from the floor (figures 6, 13, and 14).

The number of thermocouples and their positions were arbitrarily picked for the metal kilns. They were located where it was assumed that temperatures representative of the maximum, minimum, and average conditions within the kilns would be found (fig. 7).

WEIGHT DATA

The weighing procedure was standard throughout the study. All wood was carefully weighed before being placed in the kilns, and records were kept. The bags of charcoal from each kiln were individually weighed, and then totaled for each run.

TIME DATA

All operations were carefully timed. However, this was not a stopwatch procedure in the sense of a standard time-motion study. The time consumed between the beginning and ending of each job, with the number of men working, gave the man-hours required for the job.

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[2] Southeastern Forest Experiment Station Paper No. 73, "An Inexpensive Method for Measuring Charcoal Kiln Temperatures," by Ralph Peter, 9 pp., illus. 1956.

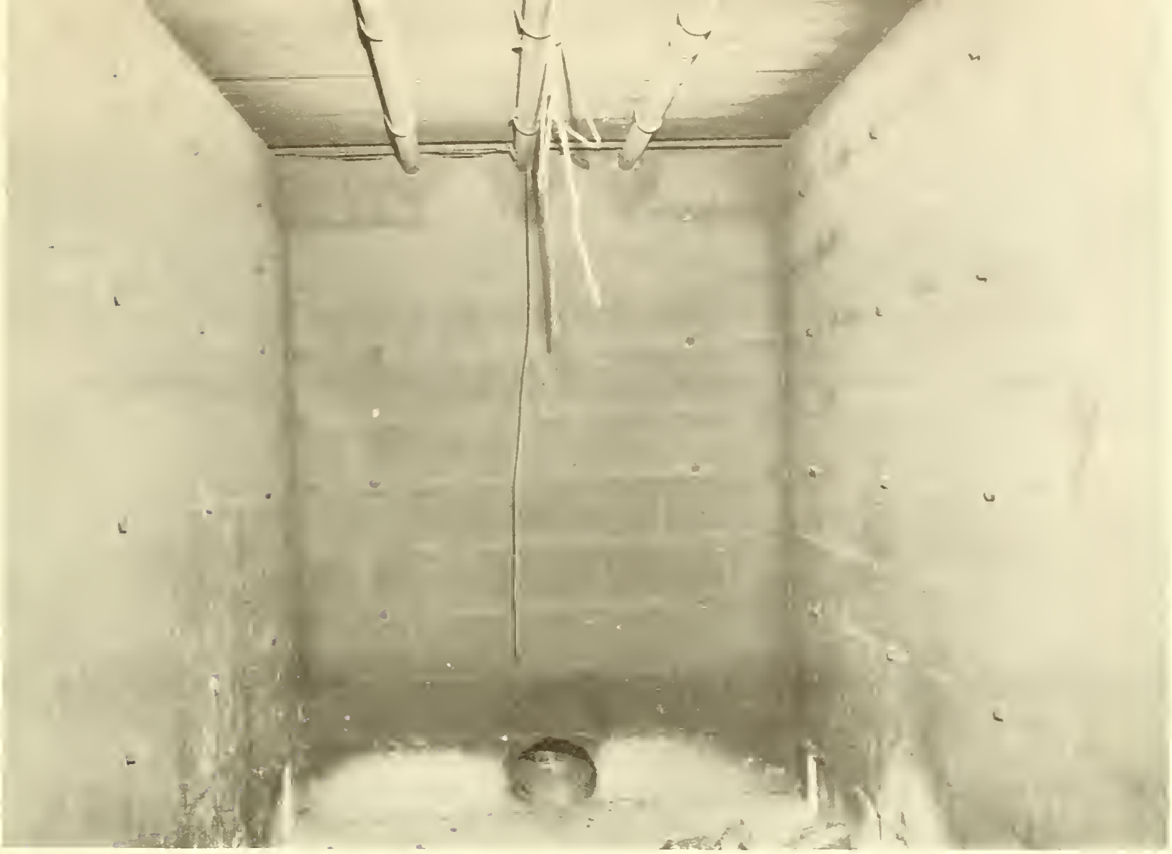

Figure 6.--Thermocouple location in the 2-cord masonry block kiln. (No. 1 is tied up here for convenience in working around the front of the kiln. It is lowered when the kiln is loaded.)

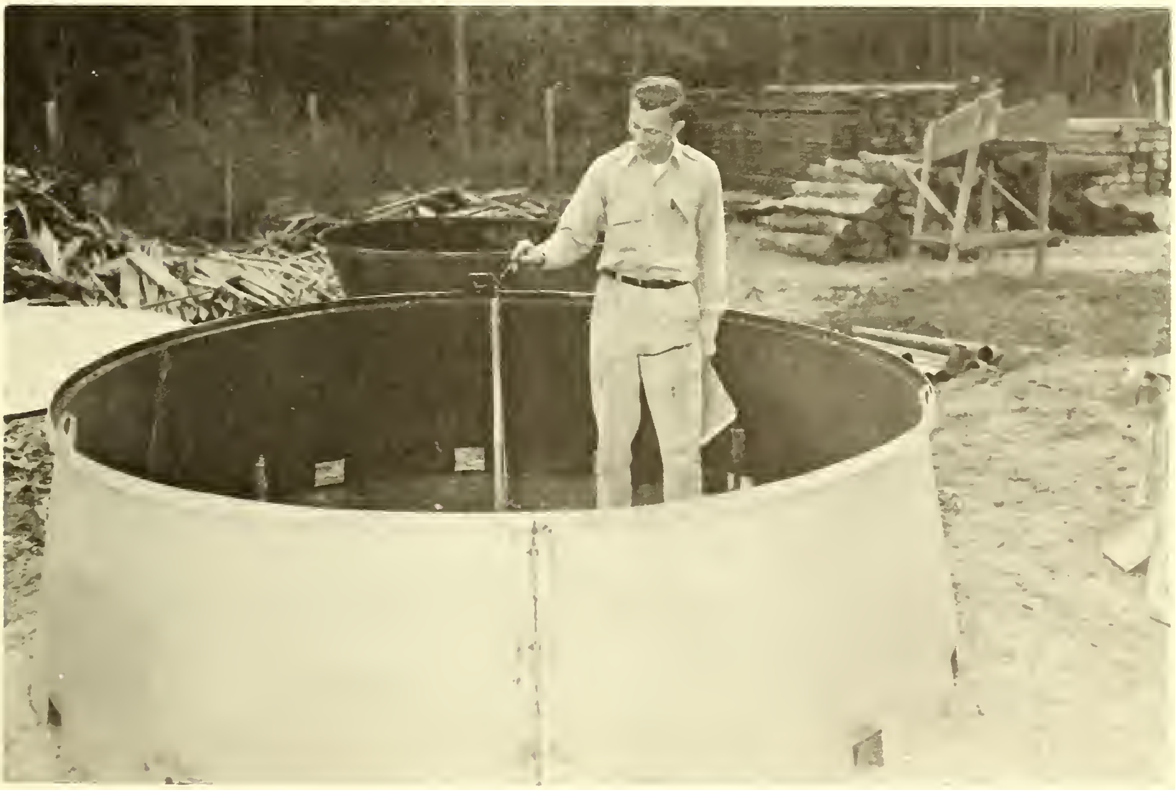

Figure 7.--Three thermocouple locations at different elevations were selected for the metal kiln.

FIRING AND COALING METHODS

½-Cord Kiln

The method of ignition and operation for these kilns was the same as that used during the past 2 years of operation on the forest. The lid was placed on the kiln immediately after loading, kerosene was poured through the center smoke pipe, and the charge ignited. Instant firing is necessary after pouring the kerosene so that fumes will not accumulate and cause an explosion when the charge is lit.

Smoke pipes were used in three of the nine holes,thus providing six air inlets. The stacks were put up before the kiln was fired, and they remained in place during the entire burn. They were spaced at equal distances around the base of the kiln.

Approximately 2 hours after ignition, the cap was placed on the central flue. The side smoke pipes promptly gave off a large volume of thick, wet, acrid smoke. Conditions were then favorable for coaling to begin. Later, as each portion of the charge became carbonized, fire appeared at the corresponding air inlet. When careful probing into this opening indicated that no more large unburned sticks remained near the hole, it was covered and banked. This procedure was followed until all draft holes were closed; smoke pipes were then removed and holes covered and banked.

This procedure differs only slightly from that recommended for the Black Rock Forest Kiln.[3/] Normally this type of kiln is ignited with the lid off, permitted to burn freely for 15 or 20 minutes, and then covered.

1½-Cord Kiln

Three burns were made in this kiln during the study. All were ignited in the same manner as that described for the ½-cord kilns, but the operational procedure was changed for the last run.

During the first two burns, the kiln was operated according to the owner's instructions. That is, on one side of the kiln smoke pipes were placed in 8 of the kiln's 15 draft holes, thereby leaving 7 air inlets open on the other side. The kiln was ignited, and after approximately 2 hours it was capped. When coaling progressed to a point where fire appeared at any hole, it was permitted to burn until probing indicated the absence of large unburned sticks in the area of that hole. The adjacent smoke pipe was then moved to the open hole and the vacated hole remained open. If two holes "came in" simultaneously, two stacks were moved. When the smoke from a stack either before or after the first move thinned out considerably and changed to a light blue color, the stack was removed and the hole was covered and banked. If a stack began to "back draft," that is, act as an air inlet, it was removed and the hole was closed.

[3/] Black Rock Forest Bulletin No. 4, "A Portable Charcoal Kiln," by Henry H. Tryon, 34 pp., illus. 1933.

The coaling period was considered to be completed when all stacks or the majority of them had been moved from their original locations and all air inlet holes had "come in." Slight probing for the presence or absence of large uncharred sticks also helped to indicate the progress of the burn. The kiln was sealed at the completion of the coaling period by removing all smoke pipes, covering and banking all open holes, and checking for air leaks.

The operational procedure for the third run in this kiln was the same as that used with the ½-cord kilns. Seven smoke pipes were inserted in alternate holes around the base of the kiln and remained stationary during the entire burn. Stacks were removed only if they were "back drafting."

2-Cord Masonry Block Kiln

A predetermined maximum temperature level was the basis for the operational procedure for this kiln during the study. Previous experience with other experimental masonry block kilns indicated that it was important to control temperatures, both from the standpoint of consistent production of quality charcoal and for the prevention of kiln deterioration due to excessive temperatures. The preferred maximum coaling temperature range of 850° to 950° F. was used. Temperature control was obtained by varying the size of the air-intake opening under the kiln door (the only air inlet).

After the kiln had been loaded, a crib of kindling, paper, and brands approximately 4 feet high and 2 feet deep, was built across the front of the charge. The door was put in place and secured with a full air-intake opening under it (3 inches high, extending across the full width of the door opening, thus providing 192 square inches of air-intake space). The port in the base of the chimney was left open, and the ceiling ports were fully opened.

Approximately 2 to 3 gallons of kerosene were poured through the ceiling ports and splashed under the door. Kerosene-soaked newspaper was placed in the opening under the door and ignited. During the succeeding 3 hours, the ceiling ports were progressively closed as the temperatures showed a gradual rise, indicating successful ignition of the charge. The port in the base of the chimney was utilized about 1 hour after firing time, then covered and sealed.

Temperature readings were periodically taken to determine the progress of the burn. Major adjustments of the air-intake space were necessary during the early part of the run to bring the charge to the desired coaling temperature. When this condition had been reached, the adjustment of the air-intake space became very critical, and a minor change had a decided effect on the temperature. Changes, however, became less necessary as the coaling period progressed, and when the temperatures held relatively steady, changes were made only if the allowable maximum was exceeded.

After the lower, rear portion of the charge reached the minimum coaling temperature, the burning time was continued for an average of 6 hours. The air intake port was then closed, but the chimney was left open for approximately 2 hours before the kiln was completely sealed.

RESULTS OF THE STUDY

It must be pointed out that many variables enter into the production of charcoal, and the presence or absence of any one or a combination of several will drastically change the entire picture. This study was not designed nor of sufficient magnitude to include all combinations of these variables. The results presented here represent the man-hour requirements and production costs per ton of charcoal for "a" method of operation. Since an attempt was made to use average conditions, it is felt that these results could be used as a basis for planning a charcoal operation. Local conditions would determine the necessary changes and adjustments.

Charcoal Yield

Acceptable charcoal was produced in all test runs, as indicated in a chemical analysis of several samples removed from each charge (table 1).

Table 1.--Summary of chemical analysis of charcoal from test runs at Bladen Lakes State Forest, December 1956

Kiln type and capacity	Runs	Analysis of charcoal: Moisture content	Volatiles	Ash	Fixed carbons
	Number	Percent			
Metal, ½-cord	4	1.77	19.17	1.78	79.05
Metal, 1½-cords	3	1.51	12.37	2.22	85.41
Cinder block, 2-cords	2	2.03	18.27	1.81	79.92

The amount of charcoal produced from a ton of wood (based on ovendry weight of wood) varied considerably by kiln type, being highest for the cinder block kiln and lowest for the 1½-cord metal kiln (table 2). It was expected that the masonry block kiln would produce the highest yield because it was operated under controlled temperature conditions with an attempt to hold the

Table 2.--Summary of wood weight and charcoal yield, on a basis of average per run

Kiln type and capacity	Runs	Wood weight: At 45 percent moisture content	Wood weight: Calculated ovendry weight	Brands	Charcoal yield: Lump	Charcoal yield: Fines	Charcoal yield: Total	Charcoal yield: Total based on ovendry wt. of wood
	Number	Pounds						Percent
Metal, ½-cord	4	2842	1959.65	139.25	471.75	61.50	533.25	27.35
Metal, 1½-cords	3	7372	5084.37	492.0	796.67	320.33	1117.00	21.95
Cinder block, 2-cords	2	8101	5586.90	329.50	1505.50	267.00	1772.50	31.72

temperatures under 950° F., and there was also considerably less heat lost through radiation. Lower radiational heat loss results in a smaller amount of the charge being consumed to produce the heat required for carbonization, and this in turn increases the yield. In metal kilns, it was expected that the larger kiln would produce a higher yield than the smaller one, but such was not the case. The larger metal kiln produced an excessive amount of brands, with a yield 5 percent below the $\frac{1}{2}$-cord metal kiln and about 10 percent below the masonry block kiln. This small yield may have been due in part to the inexperience of the operator, who had never worked with a unit of this size.

Temperature Comparisons

There was a wide variation in operating temperatures in the different type kilns and even between different runs of the same kiln, as shown in figures 8 through 14.

It is quite obvious that better coaling conditions (about 900° F.) prevailed for a longer period of time during the coaling phase in the masonry block kiln than in either of the metal kilns. The $\frac{1}{2}$-cord metal unit did not produce as high temperatures as the $1\frac{1}{2}$-cord metal one, which probably accounts for the higher charcoal yield in the smaller metal kiln.

In studying these temperature patterns, it must be remembered that the metal kilns were operated without temperature control, according to usual commercial practice. It might be possible to improve the operation of the metal kilns by attempting temperature control, but that was not an aim of this study.

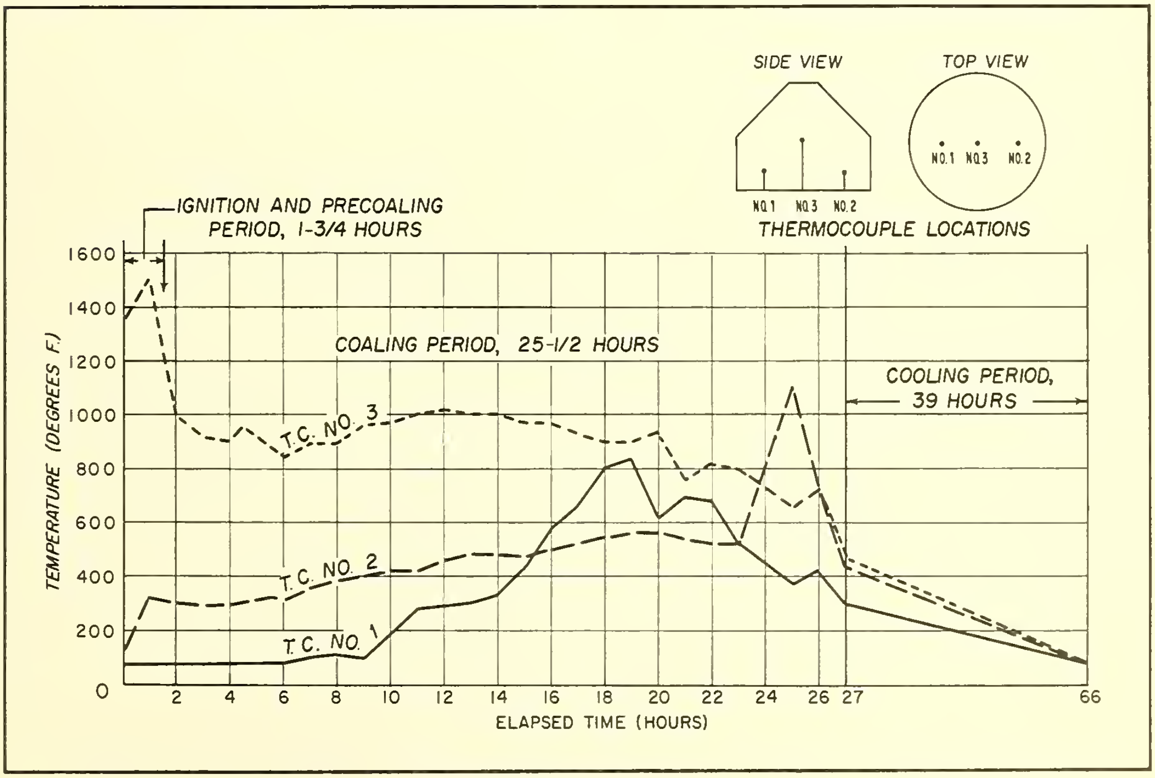

Figure 8.--Temperatures in kiln charge number 1, metal beehive $\frac{1}{2}$-cord kiln.

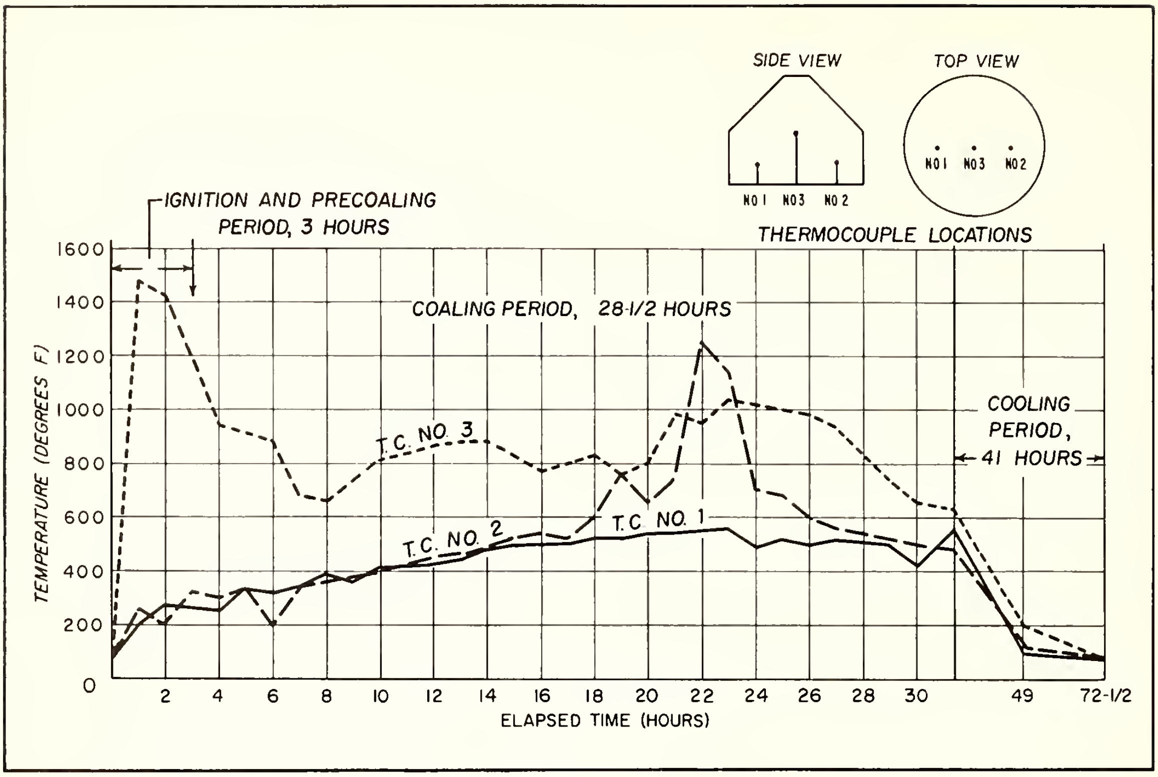

Figure 9.--Temperatures in kiln charge number 2, metal beehive ½-cord kiln.

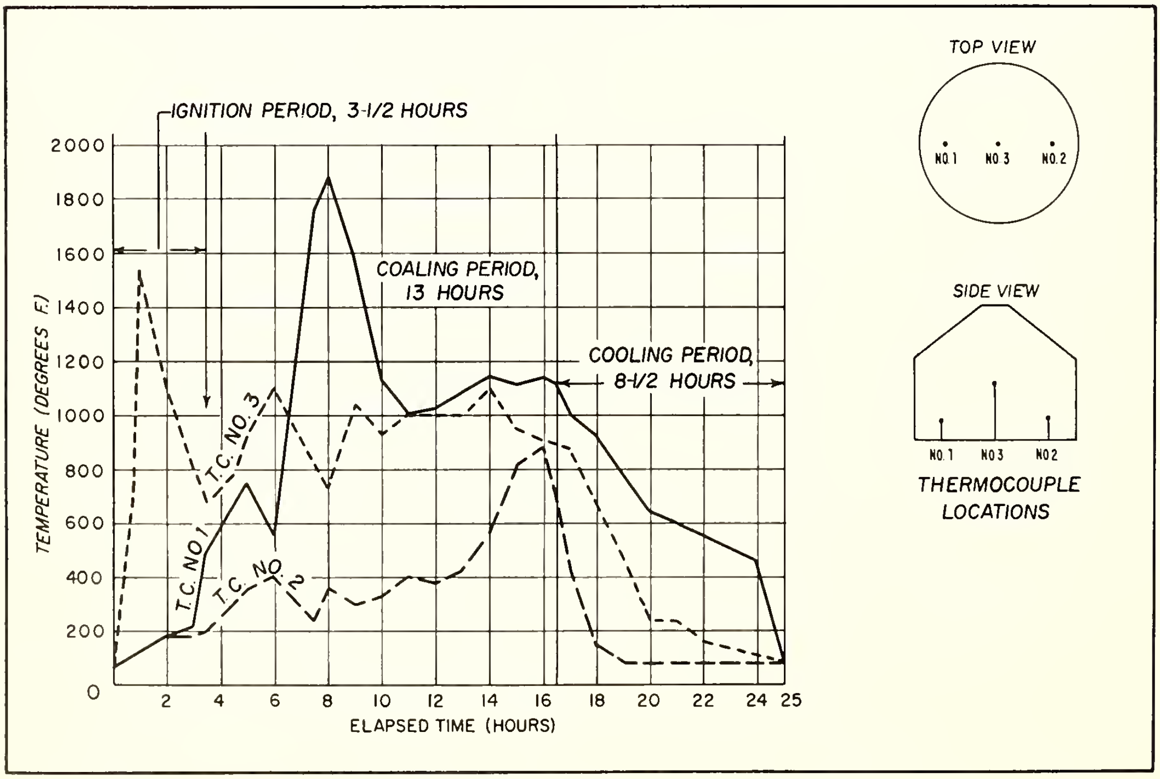

Figure 10.--Temperatures in kiln charge number 1, metal beehive 1½-cord kiln.

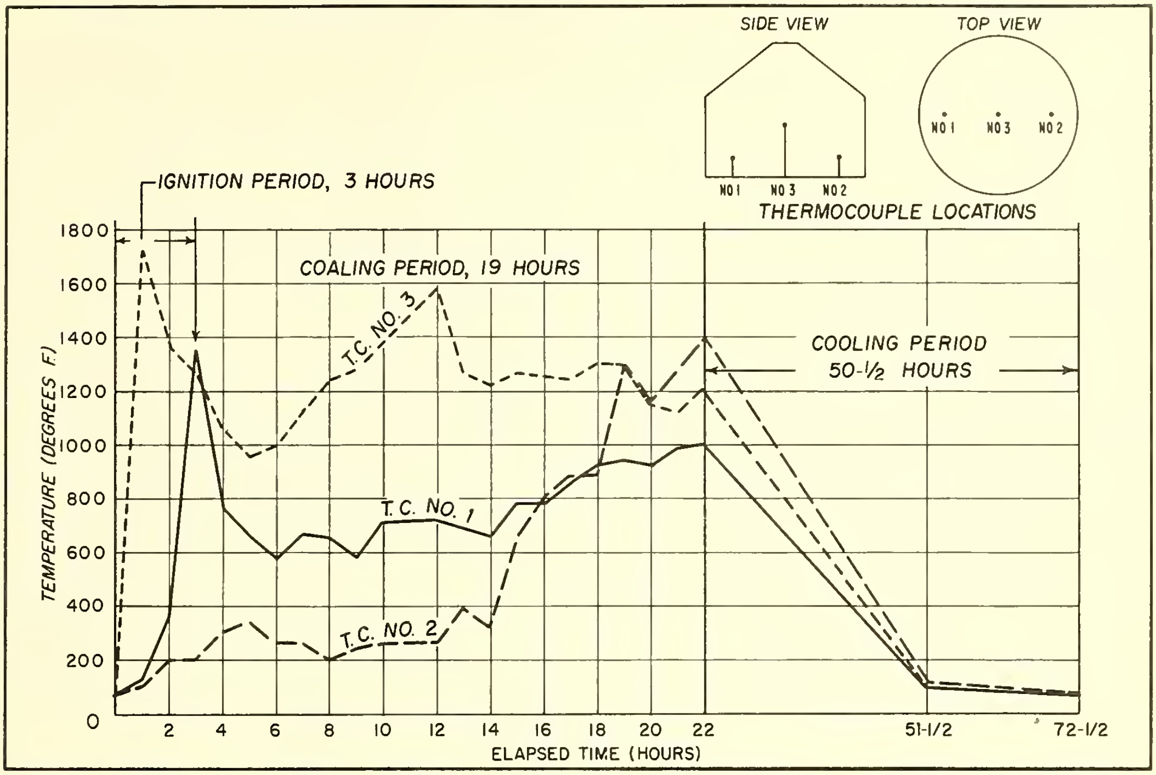

Figure 11.--Temperatures in kiln charge number 2, metal beehive 1½-cord kiln.

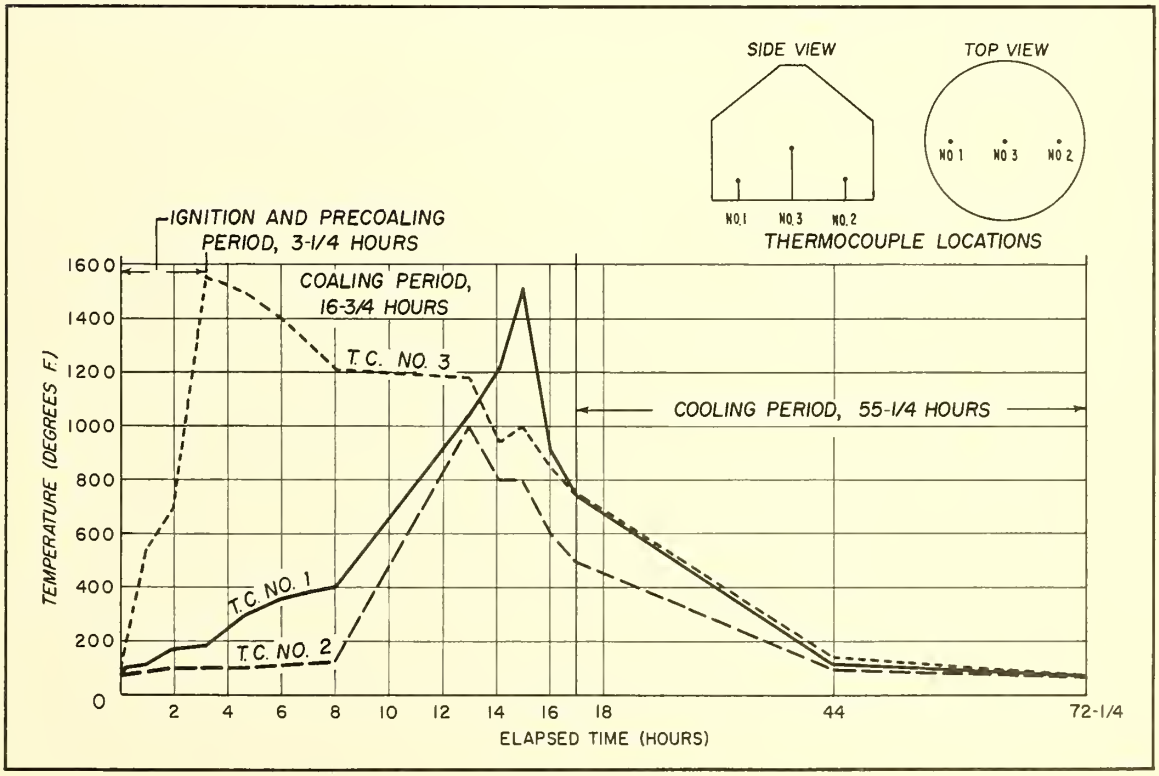

Figure 12.--Temperatures in kiln charge number 3, metal beehive 1½-cord kiln.

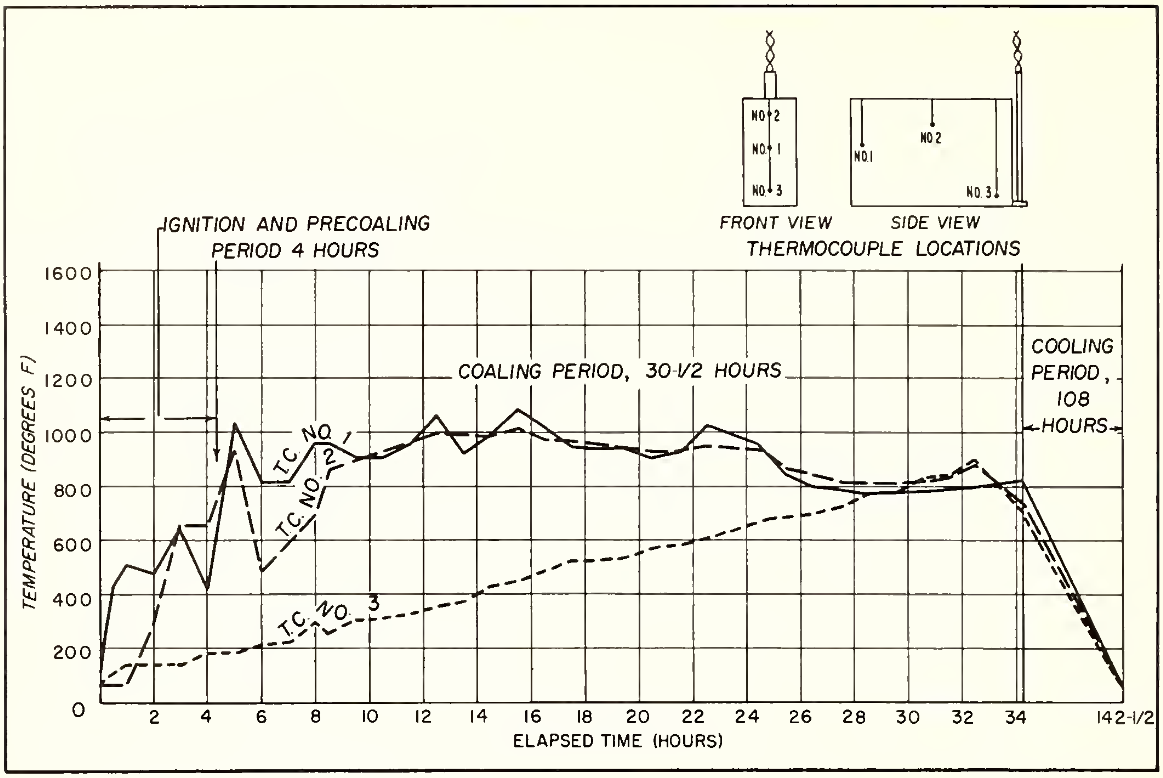

Figure 13.--Temperatures in kiln charge number 1, cinder block kiln.

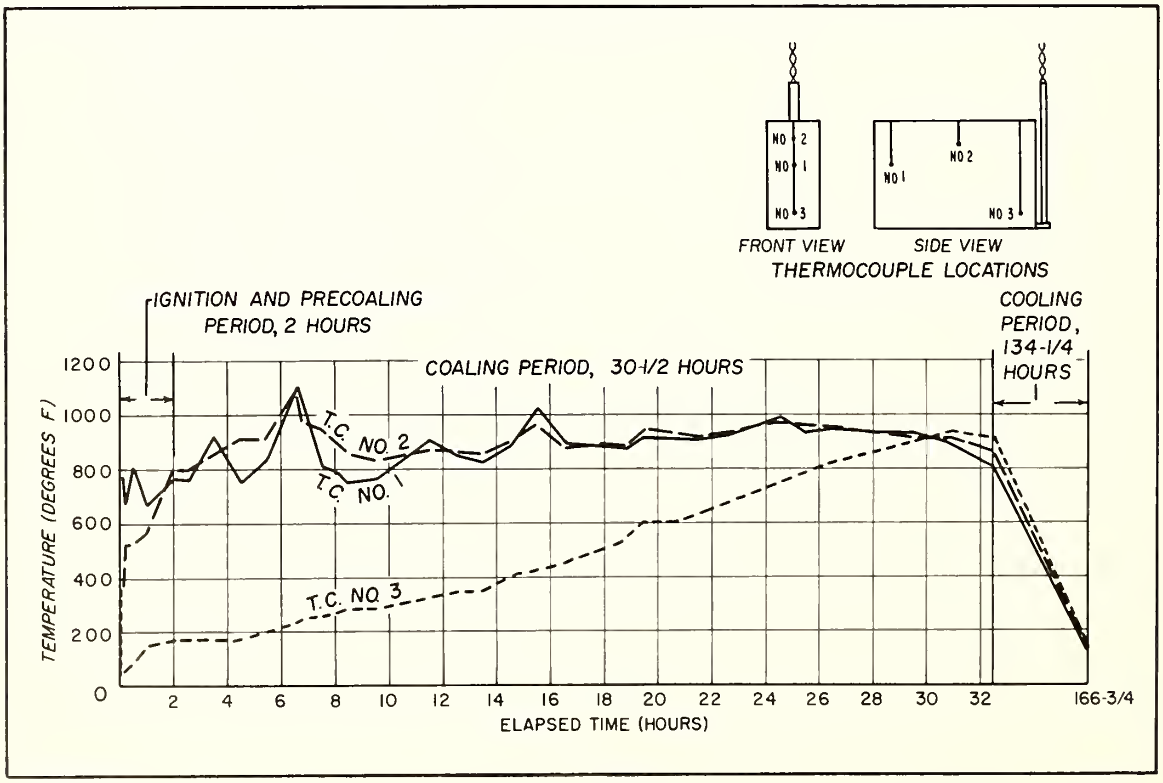

Figure 14.--Temperatures in kiln charge number 2, cinder block kiln.

Analysis of Costs

The direct labor costs for producing a ton of charcoal in the three types of kilns vary only slightly. These costs are based on estimated labor requirements at $1.00 per hour. Also, they are based on the theory that for efficiency and conservation of labor, a sufficient number of kilns of each type would be operated at one time to keep 2 or 3 men employed full time. Roughly, this would mean that 2 men would require about twelve ½-cord kilns or five 1½-cord kilns or three 2-cord masonry block kilns to keep them occupied for 40 hours per week. On a basis of this limited study, the direct labor cost varies only from $23.35 to $26.12 per ton of charcoal produced (table 3).

A closer look at the estimates of direct labor cost indicates that the masonry block kiln is considerably cheaper to load and unload, but it costs more for labor during the burning and cooling periods (the reason being that close temperature control and inspection is needed to maintain optimum coaling conditions). This extra labor, however, is more than offset by higher yields and lower depreciation.

Table 3.--Summary of direct labor cost data from charcoal runs[1]

Kiln type and capacity	Runs	Cost per ton of charcoal produced					
		Loading	Burning	Cooling	Unloading	Weighing	Total
	Number	Dollars					
Metal, ½-cord	4	8.61	3.46	.99	9.82	3.30	26.12
Metal, 1½-cords	3	8.82	3.35	.50	8.57	2.12	23.35
Cinder block, 2-cords	2	5.41	5.95	3.67	6.91	2.12	24.05

[1] Since the direct labor costs are based on the labor requirement at $1.00 per hour, this table also shows the number of man-hours required to produce a ton of charcoal.

Not included in table 3 is the stumpage cost of the wood, cutting, or handling costs. Such costs vary widely and are often the major cause for success or failure. At Bladen Lakes State Forest these costs amounted to $12.00 per cord for wood stacked on the yard at the charcoal kiln. On a basis of charcoal yields obtained in these test runs, the wood costs per ton of charcoal amounted to $28.68 for the ½-cord metal kilns, $35.73 for the 1½-cord metal kilns, and $24.73 for the 2-cord cinder block kiln.

An additional cost that must be charged against production is depreciation. The ½-cord metal kilns reportedly range in price from $400 to $800 per cord capacity, averaging $600, the 1½-cord metal kilns cost about $300 per cord capacity, and the 2-cord cinder block kiln about $250 per cord capacity. The life of these kilns is unknown but it has been roughly estimated that they will last about 200 burns. For the metal kilns this represents about 2 years; for the block kiln, which requires more time for each coaling and cooling, it represents about 4 years. On this basis, depreciation costs on these kilns at 5 percent interest per ton of charcoal would be $6.25 for the ½-cord metal kilns, $4.42 for the 1½-cord metal kilns, and $3.44 for the 2-cord masonry block kiln.

Summarizing these, produces the following "break-even" cost tabulation:

Kiln type and capacity	Labor	Wood	Depreciation	Total
		(Dollars per ton of charcoal)		
Metal, ½-cord	$26.12	$28.68	$6.25	$61.05
Metal, 1½-cord	23.35	35.73	4.42	63.50
Cinder block, 2-cord	24.05	24.73	3.44	52.22

It will be noted that the items of overhead, maintenance, and profit and risk have been omitted from the above costs. Since these variables are so closely allied with local conditions, operating methods, marketing procedures, and desired returns, it appears preferable for the purpose of direct cost comparisons to eliminate them in this study. When a complete charcoal operation is planned, they should be determined locally and included.

CONCLUSIONS

In the test runs on three types of small charcoal kilns, the total break-even costs ranged from $52 to $63 per ton of charcoal produced. Since this is about the average wholesale price of bulk charcoal in this area, a business based on the operation of any of these kilns would be on a marginal basis, unless some items of cost could be reduced.

There is little opportunity for reducing the cost of the structures used in the Bladen Lakes studies or reducing the labor cost of operating a single kiln at the minimum wage of $1.00 per hour. However, more efficient use of labor might be achieved by mechanizing the handling of materials or by operating a battery of kilns. Also, a major cost reduction can be accomplished by obtaining cheaper wood. Some operators use mill waste or woods waste. Others use cull trees that need to be removed. Such an operation would be in lieu of deading cull trees to improve forest stands, and part of the cost can be charged against forest management. Larger kilns will also accomplish a saving, as indicated by recent experimental work at Athens, Georgia, where labor and depreciation costs of a 7-cord cinder block kiln were less than those for the ½-, 1½-, or 2-cord kilns at Bladen Lakes.

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